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COMPUTER SCIENCE MEETS AUTOMATION

VOLUME II

Session 6 - Environmental Systems: Management and Optimisation

Session 7 - New Methods and Technologies for Medicine and Biology

Session 8 - Embedded System Design and Application

Session 9 - Image Processing, Image Analysis and Computer Vision

Session 10 - Mobile Communications

Session 11 - Education in Computer Science and Automation

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Preface

Dear Participants,

Confronted with the ever-increasing complexity of technical processes and the growing demands on their efficiency, security and flexibility, the scientific world needs to establish new methods of engineering design and new methods of systems operation. The factors likely to affect the design of the smart systems of the future will doubtless include the following:

- As computational costs decrease, it will be possible to apply more complex algorithms, even in real time. These algorithms will take into account system nonlinearities or provide online optimisation of the system's performance.
- New fields of application will be addressed. Interest is now being expressed, beyond that in "classical" technical systems and processes, in environmental systems or medical and bioengineering applications.
- The boundaries between software and hardware design are being eroded. New design methods will include co-design of software and hardware and even of sensor and actuator components.
- Automation will not only replace human operators but will assist, support and supervise humans so that their work is safe and even more effective.
- Networked systems or swarms will be crucial, requiring improvement of the communication within them and study of how their behaviour can be made globally consistent.
- The issues of security and safety, not only during the operation of systems but also in the course of their design, will continue to increase in importance.

The title "Computer Science meets Automation", borne by the 52nd International Scientific Colloquium (IWK) at the Technische Universität Ilmenau, Germany, expresses the desire of scientists and engineers to rise to these challenges, cooperating closely on innovative methods in the two disciplines of computer science and automation.

The IWK has a long tradition going back as far as 1953. In the years before 1989, a major function of the colloquium was to bring together scientists from both sides of the Iron Curtain. Naturally, bonds were also deepened between the countries from the East. Today, the objective of the colloquium is still to bring researchers together. They come from the eastern and western member states of the European Union, and, indeed, from all over the world. All who wish to share their ideas on the points where "Computer Science meets Automation" are addressed by this colloquium at the Technische Universität Ilmenau.

All the University's Faculties have joined forces to ensure that nothing is left out. Control engineering, information science, cybernetics, communication technology and systems engineering – for all of these and their applications (ranging from biological systems to heavy engineering), the issues are being covered.

Together with all the organizers I should like to thank you for your contributions to the conference, ensuring, as they do, a most interesting colloquium programme of an interdisciplinary nature.
I am looking forward to an inspiring colloquium. It promises to be a fine platform for you to present your research, to address new concepts and to meet colleagues in Ilmenau.

Professor Peter Scharff
Rector, TU Ilmenau

Professor Christoph Ament
Head of Organisation

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T. Riedel / C. Thiel / C. Schmullius

A reliable and transferable classification approach towards operational land cover mapping combining optical and SAR data

ABSTRACT

The availability of up-to-date and reliable land cover maps is of great importance for many earth science applications. For the generation of operational land cover products the development of semi- and fully-automated classification strategies is essential. Aim of this paper is to make a contribution towards this problem. The study area is located in northern Thuringia, Germany, including mainly forested regions like the eastern part of the low mountain range Harz as well as intensively used agricultural areas. An object-based hierarchical classification scheme for the derivation of basic land cover classes using both optical and SAR data is presented. By the integration of textural features in the classification process the classification accuracy could be improved significantly, especially in the context of urban areas. In this study the power of the neighboring grey level dependency matrix – rarely used in the field of remote sensing – is demonstrated.

INTRODUCTION

Earth observation represents a unique method for large area land cover mapping providing spatially consistent and multitemporal information. The availability of reliable and up-to-date land cover information is required for a multitude of regional to global applications such as land cover change studies, ecological monitoring, map updating or the control of national and international treaties [1]. For operational applications the development of robust, transferable, semi-automated and automated approaches is of special interest. In regions with frequent cloud cover such as Central Europe the number of suitable optical data is often limited. The all-weather capability is one major advantage of SAR data beyond optical systems. Furthermore, radar sensors provide information complementary to those contained in visible-infrared imagery. The benefit of combining optical and SAR data for land cover mapping was demonstrated in [2, 3, 4].

Emphasis of this study was to develop a robust and transferable methodology for the generation of basic land cover products including a limited number of optical data only, but exploiting the information content of multitemporal SAR data. Regarding operational applications the processing chain should comprise a high potential for automation.

EXPERIMENTAL DATA AND METHODOLOGY

The study site is located in northern Thuringia, Germany including mainly forested areas characterized by rough topography like the low mountain range Harz as well as intensively used agricultural areas like the “Goldene Aue” east of Nordhausen. From April to December 2005 optical and SAR data were acquired continuously over the test site building up a comprehensive time series. HH/HV-polarized ASAR APP and ERS-2 data were recorded nearly simultaneously providing C-band data at all polarizations.

Emphasis of this study was to develop a robust and transferable classification scheme for the derivation of basic land cover maps. The proposed processing chain is composed of three main stages (Fig. 1). First, all EO-data were pre-processed on base of widely used standard techniques. As parts of the test site are characterized by significant topography, the normalization procedure introduced by Stussi et al. [5] was applied to all SAR data. Image segments were delineated on base of the optical EO-data using the multiresolution segmentation approach [6] implemented in the eCognition software. In the next processing step, potential training sites were selected automatically for each land cover class on base of a decision tree. As the application of fixed thresholds sometimes will fail, the thresholds values specified in the nodes of the decision tree will be adapted to each EO-scene separately. To achieve this, for each land cover type an optimal set of characteristic image parameters was defined by analyzing the time series available in a systematic manner. Additionally, information reported in literature and libraries (e.g. European RAdar-Optical Research Assemblage library - ERA-ORA) were considered. By the combination of this expert know-ledge about typical target characteristics (e.g. low reflectance of water bodies in the near infrared) and histogram analyses, it is possible to assess scene-specific threshold values. In the third stage of the proposed classification scheme the identified trainings sites will be used as input for a supervised maximum-likelihood classification. The final land cover category assigned to each image object corresponds to the most frequent class per image segment.

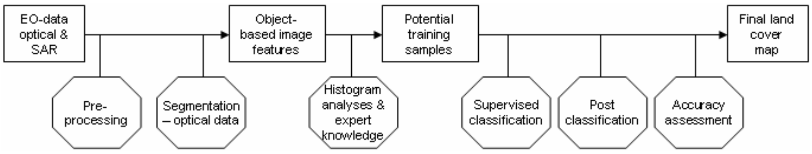

Figure 1: Proposed processing chain

For the detection of urban areas texture parameters are a valuable tool. In this study the potential of various texture measures such as standard derivation and parameters derived on base of the grey-level co-occurrence matrix were investigated. Additionally, the neighboring grey level dependency matrix (NGLD) was calculated [7]. The relation r used for the computation of the NGLD-matrix was defined as a difference of 0.1 between neighboring pixels at a distance d of two pixels. R was selected on base of a statistical analysis of various test areas indicating a proportion of > 40% of neighboring pixels with a difference of at least 0.1 in urban areas. Besides this, urban areas are characterized by a high radar backscatter at C-HH. To account for this behavior following parameter, hereinafter called UADP, was calculated on base of the NGLD matrix:

$$UADP = \sum_{a=0}^{gz-1} \sum_{n_r=0}^{N} Q_d(a, n_r) * n_r * a \qquad (1)$$

where a = radar backscatter at HH-polarization
n_r = number of pixels satisfying the relation r
Q_d = NGLD matrix value - number of occurrences of combination a and n_r

The potential of the textural parameters investigated was evaluated by visual interpretation, separability analyses as well as by a comparison of the achieved map accuracies.

The quality of the final land cover products was assessed by calculating the confusion matrix and the kappa coefficient for fifty randomly distributed reference points per land cover category. The class membership of each target was specified on base of official land information GIS layers, high resolution optical and field data.

RESULTS

As outlined in the previous chapter textural features in conjunction with spectral and backscatter information were used to map urban area extent. The power of texture information for such applications using medium resolution earth observation data was demonstrated by [8, 9, 10]. In this study several textural measures extracted from multitemporal optical and SAR data were investigated. Figure 2 illustrates eclectic texture parameters derived from HH-polarized ASAR APP data acquired on April 22, 2005. Best overall performance and relatively stable results over time were found for the NGLD matrix approach, which was therefore used for the mapping of urban areas.

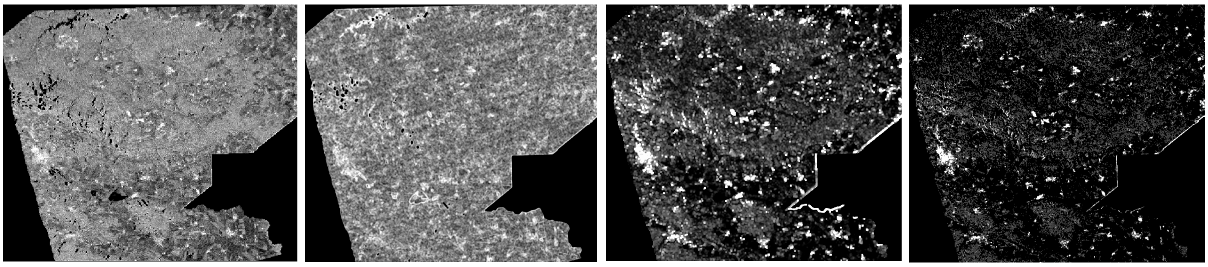

Figure 2: Eclectic texture features derived from HH-polarized ASAR APP data acquired on April 22, 2005 – from left: original image, co-occurrence entropy, standard derivation, UADP

As outlined above, the second step of the proposed processing strategy compromises the automatic selection of potential training samples on base of a decision tree. The absolute threshold values at each node of the decision tree are estimated for each optical scene separately making use of expert knowledge in conjunction with histogram analyses. For example, in agreement with the general knowledge of reflectance properties, the analyses of the time series available and the EO-libraries showed that coniferous forest areas are characterized by a low near (NIR) and middle infrared reflectance (MIR). Figure 3 shows two histograms representing the object mean values in NIR for all segments characterized by a low reflectance in MIR. Mainly coniferous forest and – depending on growth stage – agricultural crops are selected, thereby the lower peak represents coniferous forest segments and the higher one agricultural fields. The corresponding threshold values are assessed by a histogram clustering graph approach [13], whereby the final threshold is defined as the mean between the local maximum and the adjacent local minima (minimum frequency of 5 segments or 10% of the maximum histogram value). Table lists 1 the characteristic image parameters used to compute the thresholds values for each land cover class. The remaining category open land was subdivided into sub-classes with similar spectral characteristics by histogram analysis.

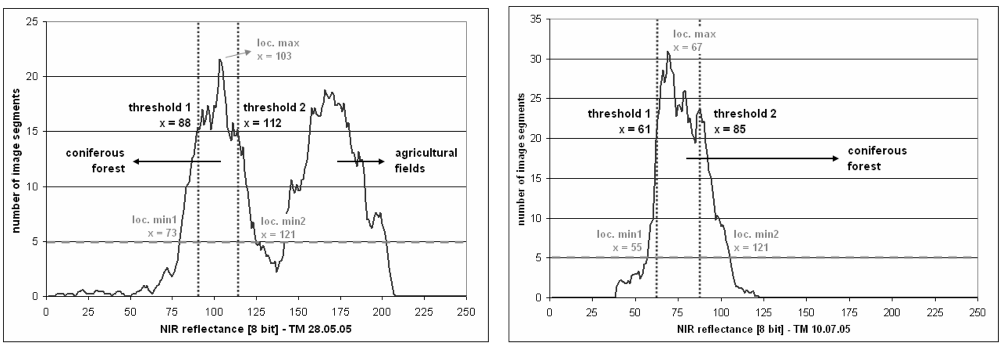

Figure 3: Threshold estimation by histogram analysis – example coniferous forest

Class	Image Parameter
Water bodies	NIR
Coniferous forest	NIR, MIR, NDVI
Dec. / mixed forest - leafoff	Green, NDVI, UADP
Dec. / mixed forest - leafon	Green, NIR, MIR
Urban areas	NIR, MIR, UADP, minimum HV-polarisation

Table 1: Characteristic image parameter used for the automatic selection of training samples

By the proposed methodology a large number of potential trainings sites will be selected. The quality of the obtained training samples was checked by a visual inspection and the calculation of the confusion matrix on base of the reference data used for the accuracy assessment of the final land cover map. For all sets of input data the user accuracy, i.e. the probability that a training sample is in agreement with the reference data, exceeds 90%. In the next processing step the training samples selected were used as input for a supervised, pixel-based maximum likelihood classification. The final land cover category assigned to each image object corresponds to the most frequent class per image segment. For validation issues the algorithm was tested for different sets of input data acquired over the Nordhausen study area in 2003 and 2005 as well as for EO-data acquired over a test site near Bonn (Table 2). The achieved classification accuracies are listed in Table 3 demonstrating the power of the proposed methodology for basic land cover mapping purposes. Regarding the SAR data the usage of ASAR APP scenes acquired at the early beginning of the growing season and after the main harvest and tillage period is highly recommended, as bare fields and fields covered by crops in an early growing stage are characterized by a low radar backscatter value. The multitemporal minimum in HV-polarisation is a useful parameter to reduce misclassifications between open land and urban or forested areas.

	Test site Nordhausen				Test site near Bonn			
	Landsat-TM/ETM	ASAR APP IS2 – HH/HV Date 1	Date2	Date3	Landsat TM / Spot*	ASAR APP IS2 – HH/HV Date 1	Date2	Date3
Set 1	21.04.05	22.04.05	10.07.05	24.08.05	03.04.05	12.03.06	02.05.06	30.07.06
Set 2	10.07.05	22.04.05	14.08.05	18.09.05	28.05.05	12.03.06	06.06.06	30.07.06
Set 3	06.08.03	11.06.03	20.08.03	14.09.03	24.06.06*	16.04.06	25.06.06	30.07.06
Set 4	22.04.03	16.07.03	20.08.03	14.09.03				

Table 2: Input data sets used

	Test site Nordhausen								Test site near Bonn					
	Set1		Set2		Set3		Set4		Set1		Set2		Set3	
	PA	UA	PA	UA	PA	UA	PA	UA	PA	UA	PA	UA	PA	UA
water	96.0	96.0	94.1	100.0	98.0	100.0	96.0	98.0	94.6	100.0	94.6	100.0	94.6	92.1
forest	100.0	99.0	99.0	89.2	100.0	99.0	100.0	99.0	94.5	92.0	97.2	84.5	96.4	90.8
urban areas	78.0	86.7	81.3	73.6	79.6	81.3	84.8	78.0	77.1	92.3	88.4	88.3	87.0	95.6
open land	94.6	92.1	83.1	91.1	93.9	93.3	91.9	94.4	97.3	92.9	91.5	96.3	96.2	95.4
overall accuracy	93.9		89.0		94.2		93.9		92.7		92.0		94.4	
kappa	0.909		0.855		0.916		0.918		0.869		0.862		0.901	

Table 3: Achieved classification accuracies – PA: producer accuracy / UA: user accuracy

CONCLUSIONS AND OUTLOOK

A combined object-/pixel-based classification scheme for the generation of basic land cover maps providing a high potential for automation has been presented. The training samples used as input for a supervised maximum-likelihood classification were selected on base of an object-based decision tree with scene-specific, flexible thresholds. The absolute threshold values were calculated by the combination of expert knowledge and histogram analyses. In order to improve the mapping accuracy for urban areas textural features extracted from HH-polarized SAR data were incorporated in the classification procedure. For validation issues the methodology was applied to different sets of input data acquired over the Nordhausen test site in 2003 and 2005 as well as near Bonn.

With the availability of polarimetric and high-resolution spaceborne X-and L-band SAR data as provided by the TerraSAR-X and PALSAR ALOS mission a further improvement is expected for both the automatic selection of potential training samples as well as the final map accuracy. The generation of more detailed land cover maps is planned in near future, especially for urban and agricultural used areas.

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